higher geographical teaching. In many respects the American Colleges are in advance of the corresponding institutions in this country, and geography is attracting increased attention on the part of some of the most energetic and progressive educationists.

COUNT PFEIL, who recently passed through London, *en route* for the Cape of Good Hope, is about to conduct a party of emigrants to Walfisch Bay, in the hope of colonising the adjacent parts of German South-West Africa.

Two pillars, erected by Diogo Cão, the first Portuguese explorer on the west coast of Africa, have recently been brought back to Lisbon. An interesting circumstance is the discovery on the pillar brought from Benguela of an inscription showing that the coast had been traced so far in 1482, two years earlier than the date usually assigned.

THE IRON AND STEEL INSTITUTE.

THE annual meeting of this institution was held on Thursday and Friday of last week, at the Institution of Civil Engineers, Sir Frederick Abel, the President, occupying the chair. After the reading of the Council's annual report Sir Frederick Abel delivered his Presidential address. He began with a reference to the losses which the Institute had sustained during the year by the death of some of its eminent members. He spoke especially of the solid services rendered to science by the late Duke of Devonshire. The Duke's wise munificence in the establishment of the Cavendish Laboratory in Cambridge University, and the important part he took in the labours of the Royal Commission on scientific instruction and the advancement of science, were described as "illustrations of his active participation in a movement of most vital importance to the maintenance of our position and influence among nations." Sir Frederick also referred to the Duke's ready consent to fill the post of first president of the Iron and Steel Institute as a proof of his appreciation of the high importance to be attached to the successful foundation of an organization of which he predicted that it would prove "a powerful instrument for the advancement and progress of the iron and steel trade of Great Britain, by promoting intercourse and interchange of knowledge between its members"—a prediction which was speedily and amply fulfilled. In his introductory address the Duke had discussed the development of iron-manufacture in most interesting and comprehensive fashion. In referring to the most extraordinary mineral wealth of the United States, he pointed out that although in 1867 the production of pig iron in America had risen to nearly 1,350,000 tons (of 2240 lbs.), the price of labour did not warrant the belief that there was any immediate prospect of the United States competing with the iron-producing countries of Europe in the open markets of the world.

Sir Frederick continued :—

A very interesting report upon the state of iron manufacture was presented by Sir Lowthian Bell to the British Association at its meeting in Dundee in 1867. A critical examination was made therein of the relative position of ourselves and Continental nations as iron manufacturers, *à propos* of the Paris International Exhibition of that year ; but in the encouraging view which that eminent authority presented of our position at the period named he was not led to make any reference to the prominence which the United States were beginning to assume among iron-producing countries. After the lapse of twelve years, however, the production of pig iron in the States had been doubled, while in another ten years it had reached a figure approximating to the average production in Great Britain during the past ten years.[1]

Viewed from our present standpoint, the observations made by our first President in his opening address of 1867, regarding the development of the manufacture of steel, are very interesting. The Duke pointed out that, "owing to recent inventions and improvements, steel had acquired an importance greatly exceeding that which it previously possessed." After referring to the then prevalent views regarding the nature of steel, and to its production by the cementation process, the puddling and the mixing processes, and the partial decarbonisation of cast iron by blowing air into pig iron melted in a charcoal hearth, he dwelt upon the interest with which the development of the Bessemer process had been watched by the iron-making world, upon the *promise* "which that process afforded of furnishing a supply of steel suitable for many most important purposes upon a scale and at a price hitherto unknown," and upon the association of the names of Joseph Heath with the first employment of manganese in steel manufacture, and of Robert Mushet with the important part played by manganese-alloys in the development of the Bessemer process. While the approaching expiration of the first Bessemer patent was referred to as likely to tend to an increase in the demand for its products, the limits which the then existing knowledge placed upon the application of the process were pointed out, and the advantages of the puddling process dwelt upon. It is interesting to note that, at any rate in Germany, these advantages have not yet been dispelled, in spite of the great revolution which the Bessemer and open-hearth processes have effected in the applications of wrought iron and steel. On the other hand, the importance which steel had acquired through the practical development of the Bessemer-process, at the date of our first President's address, was but an indication of the new era upon which the iron and steel industries were about to enter. In that year the produce of Bessemer-steel in the United Kingdom was only 160,000 tons, while open-hearth steel was not yet a staple product ; in 1890 the British production of Bessemer steel exceeded two millions of tons, while that of open-hearth steel exceeded 1·5 millions of tons.[1]

A statement made in the Duke's address of 1869, that, so far as existing knowledge went, the Bessemer process was of limited application, as only certain kinds of iron were susceptible of successful treatment by it, affords, by a comparison with the present condition of things, an interesting illustration of the continuous progress made in the successful application of advances in scientific knowledge to practical purposes. The success which crowned the efforts of Thomas, Gilchrist, Snelus, and others to render the Bessemer- and open-hearth processes efficient in their application to ores, the successful treatment of which by them appeared well-nigh hopeless in the earlier days of the Iron and Steel Institute's existence, has recently been very prominently before the public, and the members will certainly receive with special interest the communication which the Director of Naval Construction has promised us on experiments with basic steel.

In the discussion which took place at the meeting of the Institute of Naval Architects last year, *à propos* to a paper by M. J. Barba on recent improvements in armour plates, it became evident that the public were far better instructed as to progress made in such directions as this by other nations than as to advances made by ourselves ; such information as Mr. White feels warranted in affording us with respect to our progress in practical experience on the merits of basic steel as applied to shipbuilding and other naval purposes will therefore be very welcome.

From the United States interesting accounts have reached us of a continuation of the experiments with armour plates 10½ inches thick, which were commenced at Annapolis in September 1890, when an all-steel and a nickel-steel plate, from the Creusot works, were contested in comparison with a compound plate of Cammel's make. Of these, the nickel-steel plate was considered to have shown itself somewhat superior to the all-steel plate, and very decidedly superior to the compound plate ; and it is stated that Congress showed its appreciation of the importance of this result by appropriating a million dollars to the purchase of nickel ore. The second and third series of trials have been carried out at the Naval Ordnance Proof Ground at Indian Island, near Washington. The plates fired at in October last, constituting the second series of three, are described as a high carbon nickel-steel plate from the Bethlehem Iron Company, one of low carbon nickel-steel from Carnegie, Phipps, and Co.'s works at Pittsburg, and a so-called "Harveyised" plate of low carbon steel from the Bethlehem works. The description given of the Harveyising process identifies it as being a case-hardening or partial cementation treatment, the surfaces of the steel plate being hardened by carbonization (and by a supplementary chilling process), and the increase in carbon dying away towards the interior of the mass. In the trials of these plates, that of high carbon nickel-steel appears to have stood the best, but the effect of the Harveyising process upon the powers of resistance of the low carbon steel plate seems to have afforded indications of beneficial effect such as to warrant the application of the process to nickel-steel plates included in the third series, fired at last November, and which comprised a high carbon nickel-steel plate from Carnegie, Phipps, and Co., a low carbon Harveyised nickel-steel plate from the same makers, and a high cabon Harveyised nickel-steel plate from the Bethlehem Company. In all the nickel-steel plates, including that from Creusot tried in 1890, the amount of nickel in the metal appears to have been a little above 3 per cent.

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[1] Mr. Robert S. M'Cormick, Resident Commissioner for Great Britain for the Chicago Exhibition of 1893, in a paper recently communicated to the Society of Arts upon the future trade-relations between Great Britain and the United States, gives the following figures as demonstrating that the British iron and steel industry has been outstripped in magnitude by that of the United States. In 1890 the produce of pig iron in America was 9,202,703 tons against 7,875,130 tons in the United Kingdom ; of manufactured iron, including rails, 2,820,377 tons were produced in America against 1,923,221 tons in Great Britain, and, of Bessemer steel, 3,688,871 tons were American produce, while the production in the United Kingdom amounted to 2,014,843 tons.

[1] 1891 appears to have witnessed a very remarkable falling off in the production of Bessemer steel, to the extent indeed of about 35 per cent., while the production of open-hearth steel exhibits a reduction in the past year of only 3 per cent.

Care seems to have been taken to render all conditions attending the trials as uniform as practicable, with this not unimportant difference, that very much less time was allowed to elapse, in the second and third trials, between the firing of the successive rounds than in the first experiments.

A careful consideration of the results led the Board, of which Admiral Kimberley was President, to the unanimous conclusion that the high carbon Harveyised nickel-steel plate was the best, but that one part of the plate was much superior in resisting powers to the other, which was ascribable apparently to a want of uniformity in the Harveyising or carbonising treatment. The official report is also said to have recorded the unanimous opinion of the Board that both the high carbon nickel-steel Harveyised plate and the high carbon nickel-steel untreated plate were superior to the Creusot nickel-steel plate tried in 1890.

Further trials will shortly be made of high and low carbon nickel-steel Harveyised plates, to be supplied by Carnegie, Phipps, and Co. From published analyses it appears that the high carbon nickel-steel plate manufactured by that Company contained 0·45 per cent. of carbon and 0·65 per cent. of manganese, and the low carbon plates of nickel-steel, 0·26 per cent. of carbon and 0·75 per cent. of manganese.

The *New York Sun*, with what appears, from the reported results, to be very justifiable sentiments of pride, winds up an account of the results arrived at with the remark that they show that America now stands at the top in the excellence of her ship-armour; and certainly our friends of the Bethlehem and Pittsburg Steel-works are to be warmly congratulated upon their achievements in this new direction.

Although the trials in the United States seemed to establish a marked superiority of nickel-steel plates over the compound plates of J. Brown and Co.'s manufacture, it is interesting to notice that this eminent firm is gallantly striving to maintain the high position which exhaustive trials had secured to that form of plate, as efficient armouring for ships of war, and that recent trials at Shoeburyness and at Portsmouth of experimental compound plates which have been submitted to a supplemental process devised by Captain Tressider, late Royal Engineers, seem, so far as I can learn, to have demonstrated that powers of resistance and endurance, much exceeding those of the compound plates tried in the United States and in the Ochta experiments of last year, can be secured to these structures. I have reason to hope that we shall receive a communication ere long on the interesting results which are being obtained in this direction.

My reference to the rapid advance which has been made in the United States in the manufacture of armour plates will recall to the minds of many here present the memorable visit of the Institute to America in 1890. The valuable record of that visit presented to us a few months ago by the American Institute of Mining Engineers, in the form of a portly volume, embracing full accounts of the proceedings and the papers read and discussed at the international meetings at New York and Pittsburgh, constitutes an important work of reference, as well as an interesting memento of one of the most notable events in the history of our Institute. And now, thanks mainly to the self-sacrificing exertions of our much-esteemed past President, Sir Lowthian Bell, we have been able to match this American volume with a companion work, the interest and value of which it would, I venture to say, be difficult to over-estimate. The series of monographs by Sir Lowthian Bell and other highly competent authorities which are embraced in this special volume (aptly named "The Iron and Steel Institute in America"), will certainly receive careful study—productive both of profit and of pleasure, at the hands not only of members of the Institute, but also of our trans-atlantic friends who so cordially received us; and our warmest thanks are due to the joint authors of this work, and especially to Sir Lowthian Bell, who, besides contributing some of the most valuable of its contents, undertook the arduous task of editing the volume; and I beg leave heartily to congratulate him upon the realization of his wish, that the completed work should make its first appearance in public at this meeting.

An interesting illustration afforded by the inaugural address of the Duke of Devonshire in 1869 of the advance made in the knowledge at the disposal of the iron and steel maker, is found in his observations on the relations of carbon to iron and steel, a subject which I had occasion to discuss in some detail in my opening address last year, in reference to the then recent interesting investigations in that direction; a subject on which we may still hope to have further light thrown by the continued researches of Osmond and others. The very complete and systematic manner in which existing knowledge on this subject is treated in the first part, recently published, of Dr. Hermann Wedding's new edition of his *Handbuch der Eisenhüttenkunde*, calls for the highest commendation.

The importance of pursuing the investigation of problems such as the conditions most favourable to economy in the use of fuel in the blast furnace, and conditions to be fulfilled in the form and dimensions of the furnace for ensuring efficiency and economy of working, were dwelt upon by the Duke of Devonshire in his comprehensive address, and reference was made to the elaborate inquiry into the chemical operations occurring in the blast furnace upon which Sir Lowthian Bell had then for some time been engaged. The interesting results arrived at by him, and the instructive discussions to which they and the conclusions based upon them gave rise, are memorable illustrations of the progress in the application of scientific research and reasoning to the study of metallurgic operations, in the promotion of which the Iron and Steel Institute has of late years played an important part, and the most recent outcome of which, in connection with the production of pig iron, is to be found in the remarkable achievements recounted by Mr. Gayley in his paper on the development of American blast furnaces, which was one of the most noteworthy communications dealt with at the New York meeting in 1890.

In directing attention to that paper in my address a year ago, I spoke of the reference made by Mr. Gayley to the importance of the elaborate series of investigations carried out, nearly a quarter of a century ago, by Sir Lowthian Bell on the chemistry of the blast furnace. I have had occasion since then to refresh my memory with regard to the ground covered by the work which our ex-President then carried out, and I must freely confess that I had no recollection of its extent nor of the mass of interesting and important experimental data accumulated by him, until I lately referred to the comprehensive and systematic investigations on the chemical phenomena of iron-smelting, which he communicated in detail to the meeting of the Institute at Merthyr in 1870. His paper on the chemistry of the blast furnace, to which I had the pleasure of listening at the Chemical Society in 1869, deals with the circumstances and conditions attending the union of iron with carbon in the blast furnace, and gives interesting results bearing upon the question of the temperature at which carbon is deposited in a finely-divided state in ironstone when it is exposed to the waste gases, rich in carbonic oxide, of the blast furnace; and the subject is discussed more definitely, by the light of additional experimental information, in Sir Lowthian Bell's admirable work on the "Principles of the Manufacture of Iron and Steel," published in 1884. He there demonstrates the readiness with which carbon is desposited in iron sponge from carbonic oxide at temperatures up to a dull red heat, examines into the question whether the presence of iron in the metallic state in iron ore is indispensable for determining the dissociation of carbonic oxide, and, after concluding in the negative, and demonstrating that metallic iron is not more active in this respect than its oxide, he refers to trials made by him of the power of several other metals and metallic oxides to effect the dissociation of carbonic oxide.

In the researches communicated in 1870 to the Merthyr meeting, the whole of these experiments are given and discussed, and it is to be regretted that the interesting results arrived at did not receive greater publicity than they met with in the Transactions of a young technical Institute, then comparatively unknown in the scientific world, and in which the results of original scientific research would scarcely be sought for.

Without venturing to enter into the details of these researches, I may mention that experimental evidence favoured the conclusion that the carbon-impregnation of an iron ore by dissociation of carbonic oxide takes place at as low a temperature as de-oxidation, which, in the case of Cleveland ore, occurs at 200° to 210° C. (392° to 410° F.), and that freshly reduced spongy iron, at about that temperature, reduces carbon from carbonic oxide to an extent corresponding to 20–24 per cent. of its weight, but that, as the temperature approaches a red heat, the deposition of carbon diminishes considerably in amount.

The results of many experiments with other metals and their oxides showed that zinc, tin, chromium, and silicon, and their oxides are neither reduced by carbonic oxide at a temperature of about 420° (that of melted zinc), nor give rise to deposition of carbon; that copper and lead are reduced at temperatures up to a red heat, without deposition of carbon; that the higher manganese oxides are reduced to protoxide below a red heat without impregnation by carbon; but that nickel, and in a smaller degree cobalt, suffer reduction from their oxides, with deposition of carbon.

Sir Lowthian Bell, while conducting his experiments at temperatures considerably below those prevailing at the particular positions in the blast furnace where the production of pig iron was believed to be effected, did not have recourse to so low a temperature as that at which Messrs. Mond, Langer, and Quincke, after having demonstrated (what appeared, in the absence of an acquaintance with Bell's results, a novel observation) that carbon was separated from carbonic oxide by passing the gas over nickel at a high temperature, found that this metal actually entered into the composition of the gas. Thus they started from the point, in this particular direction, up to which Sir Lowthian Bell had carried his observations twenty years previously, and obtained the remarkable nickel-carbon-oxide compound referred to by me in my address last year, which they have since succeeded in producing upon so considerable a scale as to afford prospect of its acquiring industrial importance.

In the description of their earliest results, they stated that attempts to produce similar combinations of carbon oxide with other metals, including iron, had failed. By persevering with research in many very varied directions, and especially with iron, they at length succeeded in volatilizing notable, although small, quantities of the latter metal in a current of carbonic oxide, by using the finely-divided pure iron obtained by reducing the oxalate in a current of hydrogen at the lowest possible temperature (about 400° C.), by allowing the product to cool in hydrogen to 80°, and then by passing a current of carbonic oxide over the spongy metal. The gas, after this treatment, was found to impart a yellow colour to a colourless flame, and if conducted through glass tubes heated to between 200° and 350° C., it deposited a metallic mirror; at a higher temperature it furnished black flakes, which analysis showed to contain 79·30 per cent. of carbon. The quantity of iron- and carbon-oxide compound produced in this way was very small; by passing 2½ litres of carbonic oxide per hour over the metal (the latter being from time to time reheated in a current of hydrogen), the issuing gas contained not more than 0·01 grm. of iron, equal to less than 2 c.c. of the gaseous iron-compound in a litre of the carbonic oxide.

The gas-mixture, when passed through benzine or heavy mineral- or tar-oils, was partially deprived of the iron compound, and the result of examination of solutions of this kind led to the conclusion that the gaseous iron combination, analogous in composition to the nickel-carbon-oxide compound (or nickel-tetra-carbonyl), had been found, and that its formula was $Fe(CO)_4$.

In continuing their researches, Mr. Mond and Dr. Langer have succeeded in obtaining the iron compound in the form of a liquid of spec. grav. 1·4664 (at 18° C.), which distils without decomposition at 102°·8 C., and solidifies below 21° into yellow needle-shaped crystals. It is slowly decomposed by exposure to air, and when its vapour is heated to 180°, it is completely decomposed into iron and carbonic oxide. Analysis and the determination of its vapour density show the composition of the liquid to be represented by the formula $Fe(CO)_5$, and Messrs. Mond and Langer have therefore called the compound *ferro-penta-carbonyl.*

If exposed to light in a sealed vessel for several hours, it deposits gold-coloured tabular crystals having a metallic lustre like gold when dry, but becoming brown by gradual decomposition when exposed to air. These crystals appear to contain a slightly smaller amount of carbonic oxide than the liquid compound from which they are deposited. Mr. Mond and his colaborateurs are still actively engaged in pursuing the researches which have brought to light the formation of these remarkable metallic compounds, whose discovery and properties suggest possibilities in several directions of technical chemistry which will doubtless lead to interesting investigations.

The first report made by Prof. Roberts-Austen to the Alloys Research Committee of the Institution of Mechanical Engineers, bearing upon the particular investigation undertaken by him at their request, although little more than introductory in its character, is full of interest, and of importance not only on account of the valuable information it furnishes regarding the method of investigation adopted by him and of the preliminary results attained by its agency, but also because of the interesting discussion elicited by its presentation to the Institution of Mechanical Engineers at their meeting last autumn.

At our annual gathering a year ago we had the advantage of receiving from Prof. Roberts-Austen a description of the autographic method adopted by him for recording the results indicated by the Le Chatelier pyrometer, the efficient operation of which I had an opportunity of witnessing as a member of the Alloys Research Committee. We also heard from Sir Lowthian Bell that he had already successfully and very usefully applied this pyrometer to determine the temperature of the blast entering a furnace at a considerable distance from the point of observation. We shall, I trust, have the advantage of learning the results of further experience by Sir Lowthian and others in the practical application of this much-needed instrument in conjunction with the automatic recording system used by Prof. Roberts-Austen; the observations made by the present President of the Institution of Mechanical Engineers, by Mr. Henry M. Howe, of Boston, and by others at the discussion of the Professor's report, demonstrated that several valuable applications were already being made of the Le Chatelier pyrometer and the system of continuous record of its indications. While it is satisfactory to me, as one of the earliest to use the ingenious pyrometer designed by my distinguished friend the late Sir William Siemens, to note that its trustworthiness as an indicator of temperatures up to 500° C. has been vindicated by the work of Messrs. Callendar and Smith, the accuracy and sharpness of the indications of Le Chatelier's pyrometer, the simplicity of its character, and the well established trustworthiness of its results at temperatures of over 1000° C., render it decidedly more valuable to the practical metallurgist, as well as to the scientific investigator, than any instrument of the class hitherto available. We shall none the less be glad to hear what Mr. Callendar has to tell us on the present occasion with regard to the results of his persevering and, I believe, successful labours in discovering and eliminating the defects of construction which served to destroy the confidence placed, in the first instance, on the indications afforded by platinum pyrometers.

The tendency of the discussion following the reading of Prof. Roberts Austen's report, which was shared in by Mr. Robert Hadfield, Mr. Henry M. Howe, and by some others whose right to criticism was beyond dispute, was to emphasise the necessity for caution in the application of theoretical views, regarding the laws which regulate the mechanical or physical properties of metals, to predictions as to the influence upon the properties of metals, such as iron, of particular impurities. I believe no one will be disposed to differ from the view expressed on that occasion by Prof. Arnold, that, for a thoroughly comprehensive examination into "the effects of small admixtures of certain elements on the mechanical and physical properties of iron, copper, lead, and other metals," it is indispensable to combine different lines of investigation with the particular one which Prof. Roberts Austen has so far prosecuted with very promising results.

The fame which Mr. Gruson has acquired in connection with the production of chilled iron structures, for land defence, presenting marvellous powers of resistance, must cause members of the Institute to look forward with much interest to the communication which has been promised us by the director of the Gruson Works, Mr. E. Reimers, on the manufacture and application of chilled cast iron, a subject with which, especially in regard to the selection of varieties and mixtures of iron suitable for securing a structure of metal essential to the attainment of combined toughness and hardness in armour-piercing projectiles, I was much concerned in the days of my much-lamented friend, the late Sir William Pallisser.

Another subject to which I devoted considerable attention twenty-three years ago, in co-operation with the late Dr. Matthiessen, bears directly upon some very interesting results which will be brought to your notice by my old and valued friend Colonel Dyer, of the Elswick Ordnance Works. In 1863 Dr. Matthiessen communicated to the British Association the results of some interesting researches into the chemical nature of alloys, which he followed up in 1866 with a preliminary report on the chemical nature of cast iron. In this memoir, after drawing a comparison between the physical deportment of what he terms the alloys of carbon and iron, and those of such alloys as are produced by copper with zinc and with tin, he discusses in some detail the question whether carbon exists in combination with iron, in cast iron, and expresses himself in favour of the view that white iron is not actually a chemical combination of carbon with the metal, but rather a solidified solution in it of carbon, while grey iron is a solidified solution of the same kind, with carbon mechanically intermixed. But while he supports this hypothesis by certain analogies between the specific electric conducting power of different varieties of iron and of alloys of other metals, he proposes to test the validity of his views by preparing pure iron, alloying it with various proportions of carbon, examining the physical and chemical properties of these alloys, and afterwards investigating the properties of alloys of the pure metal with various other metals and non-metals. Matthiessen's persevering endeavours to elaborate a process for the preparation of pure iron, which extended over three years, were at length crowned with success, and in 1869 I was engaged with him upon experiments with metal, obtained in the form of sponge, containing as its only impurity a minute trace of sulphur. This iron was prepared by fusing together perfectly pure and dried ferrous sulphate and sodium sulphate, completely washing the crystalline oxide thus obtained, and then reducing it to metallic sponge by heating it in thoroughly purified hydrogen. The sponge metal was welded together in the cold by powerful compression, for certain experiments; for others it was fused in very carefully prepared lime-crucibles. The experiments which it was hoped to undertake with this pure material, in the directions I have indicated, were arrested almost at their commencement by Dr. Matthiessen's death, and by the all-engrossing nature of my official labours. The process, which was elaborated with such trouble, may perhaps prove useful in connection with the investigation which Prof. Roberts-Austen has undertaken for the Alloys Research Committee of the Institution of Mechanical Engineers; but it appears to me that there is good prospect of procuring iron sufficiently pure, at any rate for certain of the experiments (when carried out upon a practical scale) which will form part of these investigations, by the very simple mode of procedure which Colonel Dyer has adopted in the production of iron containing only traces of carbon and silicon, no phosphorus, and less than two-hundreths of one per cent. of sulphur, and which affords a very interesting instance of the application of the basic furnace.

In concluding these few observations, I cannot forbear once more referring to the interesting address delivered to the members by our first President twenty-three years ago, in order to point out how strikingly its peroration illustrates the progress which has been made in the development of the steel industry during the past twenty-two years. While forcibly dwelling upon "the extraordinary influence which the manufacture of iron had come to exercise on the condition of society throughout the civilized world," the writer gives no indication of the part then played, or destined to be played, by *steel* in that civilizing influence. Even seven years later, when steel-manufacture had advanced with rapid strides, there was still great hesitation in adopting it for some of the most important purposes to which iron was applied; thus Sir Nathanial Barnaby wrote at that time, "Our distrust of steel is so great that the material may be said to be altogether unused by private shipbuilders." Yet, a few years afterwards, it had come to pass that the examples of the marvellous development in the applications of iron, to which the Duke referred in illustration of his statements, constituted the very directions in which the steel manufacturer has accomplished his most prominent achievements, and in which the use of iron is becoming a memory of the past.

The following was the list of papers to be read:—On experiments with basic steel, by W. H. White, C.B., F.R.S., Director of Naval Construction; on the production of pure iron in the basic furnace, by Colonel H. S. Dyer, of Elswick; on experiments on the elimination of sulphur from iron, by E. J. Ball, Ph.D., and A. Wingham, F.I.C.; on platinum pyrometers, by H. L. Callendar; on the manufacture and application of chilled cast iron (Gruson's system), by E. Reimers, of Magdeburg; on valves for open hearth furnaces, by J. W. Wailes; on the calorific efficiency of the puddling furnace, by Major Cubillo, of Trubia Arsenal, Spain; on a practical slide rule for use in the calculation of blast furnace charges, by A. Wingham, F.I.C.; notes on fuel, and its efficiency in metallurgic operations, by B. H. Thwaite.

The whole of these papers were read except that by Major Cubillo.

Mr. White's was the first contribution taken. His paper was founded on a number of experiments made at Pembroke Dockyard, with a view to determine the suitability of steel made by the basic process for ship-building purposes. It would be useless to attempt to summarise the results of the large amount of information contained in the paper, and in the tables, which formed an appendix to it. As a general fact, it may be said that basic steel no longer labours under the disadvantages that attended its early days, when it was undoubtedly unfit to be used as a ship-building material. The importance of the basic process to this country can hardly be overrated. The manufacture of steel on the original acid process demands a pig low in phosphorus, and this can only be prepared from a special ore, such as the hematites of Cumberland and other parts. Unfortunately, the deposits of such ore in the British Isles are very limited in extent, and it is for this reason that we have been, for years past, importing vast quantities of steel-making ore from the neighbourhood of Bilboa in Spain. This means a heavy item for freight; and it is a question whether we could, in England, stand the competition of Spain, if that country once organized her steel-making resources on a sound footing. But in any case it is desirable we should depend, as little as possible, on foreign countries for raw material, when we have such vast stocks within our own borders. In the ores of the Cleveland district and other parts, we have such deposits, but the ore contains a comparatively large percentage of phosphorus, which entirely unfits it for the old acid process of steel-making. The basic process, however, is designed to enable phosphoric pig to be used, and to judge by Mr. White's paper a fair measure of success has been attained in this direction. It would have been interesting if the paper had given details as to the pig from which the steel was made. Mr. Martell has said that no steel to meet Lloyd's requirements has been made from pig containing 3 per cent. of phosphorus, and that the basic steel which has been successful has been made from an ore low in phosphorus. It is, however, not the bulk of the phosphorus which is difficult to eliminate, but the last part, and Sir Lowthian Bell stated that he would be glad if the pig of his district did contain 3 per cent. of phosphorus instead of about half that quantity, as it would then produce a slag more valuable for fertilizing purposes. However this may be, it would have been satisfactory to have had full analyses of pig to attach to particulars of physical tests so well authenticated as those now given to the engineering world by Mr. White's paper. Another point upon which it is desirable to get information is, which process gives the best results in working on the basic principle? We have always considered it a settled matter that the open-hearth furnace was superior to the converter in this respect, so far as the quality of the product is concerned, and the discussion of last Thursday, on the whole, tended to confirm this opinion. The opposite view, however, was advanced by more than one speaker whose words should carry weight; and there is also the question of cost and quickness of production to consider. On the whole, it would seem, therefore, that the problem as to whether the converter or the open-hearth furnace should be used is still an open one; doubtless it will be settled in this case, as before, by the special requirements of the metal to be produced. As we have said, we cannot reproduce even a brief abstract of Mr. White's paper, but we can give one or two figures. One sample of basic Bessemer had a tensile strength of 30·6 tons per square inch, and an extension in 8 inches of 26 per cent. Of some pieces tested after annealing the tensile strength was about 28 tons, with an elongation of 25 per cent. One sample of basic open-hearth showed 31·3 tons per square inch tensile strength and 26·2 per cent. extension in 8 inches. We quote these figures as showing the best results, and to serve as a guide; it is doubtless unnecessary to say that they are not conclusive standing alone. The riveting tests given are valuable, but these are of a nature which cannot be epitomized.

Colonel Dyer's paper might well have been longer, as the subject of it is one of considerable importance. Pure iron is a substance at any rate difficult to get. Sir Lowthian Bell has said he has never met with absolutely pure iron. Commercially pure iron, or what might be called practically pure iron, is not uncommon. Colonel Dyer's object was to obtain a pure iron in order to determine the value of alloys. By working on the lines which he had followed, the author hoped that pure iron and steel may be produced at reasonable cost. In the first experiments the furnace was charged in the ordinary manner with pig and scrap of fairly good quality, and the charge was worked slowly, care being taken to keep the slag well saturated with lime by liberal additions of limestone. The phosphorus was reduced during the process, but the result left much to be desired in other respects. Charges composed of from one-half to four-fifths of good scrap, and one-half to one-fifth of good Swedish pig were then worked very quickly, and a remarkably pure iron was obtained, of which the following was the result of analysis:—

Combined carbon	trace
Silicon	·005
Manganese	trace
Phosphorus	trace
Sulphur	·015

This iron could only be forged in small pieces, even with the greatest care, and therefore no results could be given as to its mechanical properties. Dr. Hopkinson had determined the magnetic properties of the metal, but the results are to be reserved for the Royal Society. Speaking generally, it has been found that the metal is more easily magnetized for small magnetizing forces than any other metal hitherto tested; its coercive force is less, its magnetization is greater, than any other sample experimented with. The next stage of Colonel Dyer's experiments had for their object the utilization of ordinary scrap steel, and the production, in the basic furnace, of steel high in carbon and low in phosphorus, and at the same time to decrease the wear and tear of the furnace. The principle of the process consists in melting scrap with carbonaceous material, and the results of the experiments have shown that when a pure carbonaceous material and ferro-manganese free from phosphorus can be obtained there will be no difficulty in producing a pure carbide of iron containing only sufficient manganese for forging. The author next described the method by which the process was carried out. Nine consecutive charges were worked, with the object of producing steel containing varying percentages of carbon, to test the value of the process. The following table gives the chemical analyses and the mechanical properties of the steel of these charges:—

TENSILE TESTS.					CHEMICAL ANALYSIS.				
No.	Yield.	Break.	Elongation.	Fracture.	C.C	Si.	Mn.	P.	S.
			Per cent.						
1	14·0	22·7	44·0	F.	·11	trace	·21	trace	·030
2	14·0	23·0	41·5	F.	·10	,,	·21	,,	·030
3	18·0	27·5	32·0	F.	·16	·020	·40	·018	·022
4	21·0	30·0	33·0	F.	·21	trace	·39	·014	·026
5	20·0	31·2	32·5	F.	·25	·014	·43	trace	·019
6	23·0	34·0	26·0	F.	·24	·018	·50	·019	·024
7	25·0	35·4	20·0	F.	·30	trace	·38	·019	·017
8	25·0	43·2	18·5	F.	·53	·012	·54	·016	·028
9	24·0	45·3	14·5	F.G.	·50	·031	·60	·009	·026

The paper by Messrs. Ball and Wingham, on the elimination of sulphur, contained the results of experiments thoughtful and suggestive in themselves, even if they do not show the iron and steel maker any immediate results which he may apply. The authors found that potassium cyanide placed on the surface of molten cast iron almost completely removed the sulphur. Owing to the extreme volatility of the cyanide, it was not found possible to reduce the quantity required to within practical limits, and efforts were therefore made to find some flux which would retain, when molten, a quantity of cyanide sufficient to effect the desulphurisation. Sodium carbonate, lime, and blast-furnace slag were in turn tried. It was found that the desulphurising action was greater when the flux consisted mainly of sodium carbonate than when a less basic lime slag was used; and that in the latter case the diminution in the percentage of sulphur varied directly with the amount of added cyanide. A table is given of the results of the experiments, the best condition being obtained when 200 grains of sodium carbonate and 100 grains of potassium cyanide were used to 2000 grains of metal, when the sulphur was reduced from 0·46 per cent. to 0·06 per cent. A further experiment with sodium carbonate alone—400 grains being added to 4000 grains of metal—the sulphur was reduced from 1·11 to 0·15 per cent. With caustic soda the sulphur was reduced from 0·15 per cent. to 0·02 per cent., which is a satisfactory result. The experiments also showed the facility with which sulphur is reduced when present in large quantities, and that it is the last part which gives difficulty in removing. Metallic sodium was introduced into the bath in the form of an alloy with lead, and this had the effect of entirely removing 0·18 per cent. of sulphur.

The paper by Mr. Reimers, which was the first read on Friday, the second day of the meeting, does not call for notice, excepting, perhaps, to remark that the Council of the Institute were to blame for not taking care that the author was informed beforehand that his contribution was not of a nature which should have been submitted in the form in which it was read. Mr. Callendar's paper on "Platinum Pyrometers" is a great contrast to the last-mentioned. The prominence given to the Le Chatelier pyrometer in this country, by Prof. Roberts-Austen chiefly, has led to renewed hope on the part of those who desire to measure higher temperatures. Mr. Callendar has been amongst those who have been giving attention to the subject, and the results of his labours, which are distinctly valuable, are given in his paper, to which we would refer all practically interested in the matter. His introductory remarks on air pyrometers are interesting, and may be read with advantage by those not already acquainted with this branch of the subject; but it is of the Siemens electrical resistance thermometer, known generally as the "platinum pyrometer," that he has most to say. It has been hitherto accepted that the platinum pyrometer was subject to the serious defect of changing its zero with use. The British Association Committee of 1874 discovered this, and it has since been amply confirmed as a fact. The Committee experimented chiefly with a pyrometer in an ordinary fire at moderate temperatures of about 800° C., and they found that the resistance increased continuously with heating, and that the wire underwent rapid deterioration. They also made some experiments and suggestions with a view to remedy this defect, but they did not succeed in overcoming it. This continuous change of zero is certainly the most serious practical defect that a pyrometer can have, and there can be no doubt that the report of the British Association did a great deal to destroy confidence in this method of measuring temperature.

We cannot do better than continue Mr. Callendar's communication on this part of the subject in his own words:—

"About seven years ago, when I began making experiments on this subject at the Cavendish Laboratory, Cambridge, I was at first very much surprised to find that the platinum wires which I used did *not* undergo continuous change, even when subjected to much more severe tests than those applied to the Siemens pyrometer by the Committee of the British Association. By making further experiments, however, with a sort of imitation Siemens pyrometer, I succeeded in reproducing at pleasure the effects they had observed, and in proving to my own satisfaction that these defects were not inherent to the method, but merely incidental to the particular form of instrument on which they experimented. I found that if the wire were properly protected from strain and from contamination, the pyrometers could be made practically free from change of zero, even at very high temperatures.

"The construction of the Siemens pyrometer has not, so far as I am aware, undergone any material change since 1874. The coil of platinum wire, which forms the sensitive part of the instrument, is wound on a clay cylinder, and packed in an iron tube from 5 to 8 feet long, and about an inch or so in diameter. I have here the fine wire and the clay cylinder from a pyrometer which was recently in use at the Royal Arsenal, Woolwich. I was informed that it had never been heated above 900° C., or 1600° F., but its resistance had increased some 15 per cent., corresponding to an error of about 100° F. in the temperature measurements. When the instrument was taken to pieces it was found that the wire was quite rotten and brittle in some places, and sticking to the clay cylinder. This, I think, is sufficient evidence that the clay, or some impurity contained in it, attacks the wire, otherwise the local nature of the action could not be explained, unless the quality of the wire used was very inferior.

"I have tried several materials on which to wind the wire, but have found nothing that answers so well as mica. The plan I generally adopt is to double the wire on itself, and wind it round a very thin plate of mica, in such a way that it only touches the mica at the edges. This method gives very good insulation, even at high temperatures, and, so far as I can discover, the mica has no action on the wire even at temperatures of 1200° C.

"Another defect of the Siemens pyrometer is the iron-containing tube. Metallic vapours of any kind will attack the wire readily, and will ruin the pyrometer. It is not probable that the iron itself will be appreciably volatile at temperatures below 1000° C., but it is very likely to contain several more volatile impurities. Vapours of copper, tin, zinc, &c., rapidly render the wire brittle and useless. A comparatively small trace suffices."

Mr. Callendar's wires were inclosed in glass, a material which naturally cannot be used for high temperatures. He finds that a hard-glazed porcelain tube does very well to protect the wire, at least up to temperatures of 1200° C. A silica tube would be better, but that the author has not succeeded in obtaining. He pointed out, however, that good porcelain is not so fragile as it is generally thought to be. He has only broken one tube, and that with a hammer. He hopes, however, ultimately to be able to produce a satisfactory silica tube. The remainder of the paper was taken up with a description of the indicating apparatus, but here, again, we must refer our readers to the original paper.

Mr. Thwaites's paper is of far too formidable proportions for us to deal with in anything like detail in this notice. He describes calorimeters, pyrometers, &c., and their uses. A good deal of the matter put forward is not altogether new.

Mr. Wingham's paper on the slide rule is of value to those interested in the practical working of blast furnaces.

Mr. Wailes's gas furnace valve has been designed to give an absolutely air-tight closing, an effect which is obtained by a water seal. Illustrations were given by means of wall diagrams.

The meeting was brought to a close with the usual votes of thanks.

The autumn meeting will be held in Liverpool, but the date is not yet fixed.

THE YEARLY ADMISSIONS TO THE ROYAL SOCIETY.[1]

THE discussions that arose in connection with the revision of the Statutes of the Royal Society during the years 1890 and 1891, led me to endeavour to obtain definite data on which to found a trustworthy opinion as to the effect of the existing limitation of the number of yearly admissions on the eventual total strength of the Society, and the probable result of increasing the number beyond fifteen, the present limit.

The facts bearing on this subject, so far as I have been able to collect them from the records of the Society, are embodied in the tables annexed to this communication, for the proper appreciation of the significance of the figures in which a few preliminary explanations are necessary.

The anniversary of the Society being fixed for November 30 in each year, the customary record of the number of Fellows for any year refers to the number on that date. I have throughout regarded the date to which this number applies as being January 1 of the following year.

The annual election of Ordinary Fellows usually takes place in the first or second week of June in each year. I have considered the date to be January 1 of the same year.

The lapses, whether from death or other causes, have been treated as having occurred at the end of the calendar year in which they take place.

These assumptions have been made to simplify the various computations that the investigation required (which have been sufficiently troublesome as it is), and owing to the considerable period dealt with, forty-three years, the results will not, I believe, be sensibly affected thereby.

Unless it is otherwise specifically stated, the numbers refer exclusively to the *Ordinary Fellows*, elected at the regular annual meetings fixed for the purpose.

So far as I have been able to ascertain (for the earlier records in many particulars are defective), the number of Ordinary Fellows elected since 1848 has been 15 in each year, except on four occasions; in two years the number having been 14, and in two years 16: the average, therefore, is 15 yearly.

During the period since 1848, the number of *Royal* and *Honorary* Fellows has been about 5, and the *Foreign* Members about 50; these are included in the total number of Fellows shown in the annual reports of the Council, but will not be further considered in what follows.

The rules under which certain privileged classes have been admitted as Fellows, in addition to the *Ordinary* Fellows, have varied somewhat since 1848, but at present, apart from the persons eligible for the classes of Fellows above excluded, the only persons so privileged are Privy Councillors. The total number of *Privileged* Fellows elected since 1848 seems to have been 75, which for 43 years gives an average of 1·75 per annum.

Table I. contains a summary of the available data relating to the total number of Fellows since 1848.

The total number, excluding Royal, Honorary, and Foreign Fellows, at the commencement of 1848 was 768. I am not able to say how many of these were Fellows elected in the ordinary way, and how many were privileged, but this has no importance for my present object. From 1860 onwards the distinction between the three classes, those elected before 1848, Privileged Fellows, and Ordinary Fellows, is exhibited.

At the end of 1890, the total number of Fellows, excluding the Royal, Honorary, and Foreign Classes, was 463; of whom 26 were Fellows elected before 1848, 36 were Privileged Fellows elected since 1848; and 401 Ordinary Fellows elected since 1848.

Hence it appears that the reduction of number of Fellows, of the three classes last referred to, has been 305, and as the number of admissions of the Privileged class has not been very materially affected by the changes in the rules relating to them, it follows that virtually the whole of this large reduction is a consequence of the restriction, to 15, of the number of Ordinary Fellows elected yearly.

As the ages of the 768 Fellows who constituted the bulk of the Society in 1848 are not known, and as the conditions of election before that year differed materially from what they have been since, no very useful conclusions can be drawn from the rate of their diminution since 1848.

Assuming, however, that the number of Privileged Fellows in 1848 was, as is probable, about 50, there would remain 718 Ordinary Fellows, of whom in 43 years 692 lapsed, or at an average yearly rate of 2·24 per cent., that is rather more than 16 a year. This rate, as I shall show subsequently, does not differ greatly from that which has prevailed among the Ordinary Fellows elected since 1848, and it may therefore be presumed that the average age of the Fellows in that year did not differ greatly from the average age since.

Table II. gives, as far as available data admit, the ages at the time of election of all Fellows elected since 1848; and shows the number of years they severally survived, the average age at election, the number and average age of those who were alive in 1891, and the greatest and least ages of Fellows elected in each year.

From this table it will be seen that there has been a gradual small increase in the age at election; the average for the first 10 years having been 42·2; for the second 10 years, 43·0; for the third 10 years, 44·8; and for the last 13 years, 45·2.

The accuracy of these conclusions may be somewhat affected by the greater number of unknown ages in the earlier years, the age when unknown having been taken at the average of the group of years in which the election took place.

The least age at which any Fellow has been elected is 24, one such case being recorded. The average minimum at any election is slightly under 30, and the average maximum is rather over 63; one election at an age of 87 is recorded, and several above 70.

The oldest survivor of the Fellows elected since 1848, who alone are dealt with in this table, was 86 years of age in 1891.

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[1] "On the Probable Effect of the Limitation of the Number of Ordinary Fellows elected into the Royal Society to Fifteen in each Year on the eventual Total Number of Fellows." By Lieut.-General R. Strachey, R.E., F.R.S. Read at the Royal Society on May 12, 1892. This paper was accompanied by four tables, presenting summaries of the author's results.